

*BODY WEIGHT AND RESPONSE ACQUISITION  
WITH DELAYED REINFORCEMENT*

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The relation between body weight and responding established with unsignaled delayed reinforcement was investigated. In three experiments, naive rats were deprived to either 70%, 80%, or 90% of ad libitum weight and were then exposed to tandem variable-interval 15-s differential-reinforcement-of-other-behavior 30-s schedules. The tandem schedule defined a resetting unsignaled delay-of-reinforcement procedure. In the first experiment, speed of magazine training, acquisition of lever pressing, and final rate of lever pressing were related to body weight. In the next experiment, lever pressing was established and maintained in rats that were magazine trained at 70% of ad libitum weight but that were then exposed to the delay procedure at 90% of ad libitum weight. Responding did not change consistently either across or within subjects in subsequent conditions in which body weight was manipulated. In the final experiment, lever pressing was established and maintained with delayed reinforcement in the absence of magazine training for each of 2 rats at 70% and for 1 of 2 rats at 90% of ad libitum weight. The results further illuminate the conditions under which responding can be established in the absence of training and when such responses are reinforced only following an unsignaled delay period.

*Key words:* acquisition, reinforcement delay, body weight, tandem VI DRO schedule, lever press, rats

Contrary to conventional wisdom about the importance of both response shaping and immediate reinforcement in developing new responses, Lattal and Gleeson (1990) established and maintained responding of food-deprived rats and pigeons in the absence of response shaping or other training when such responses produced food only after unsignaled delay intervals of up to 30 s. Other experiments have shown response acquisition with delayed reinforcement to be a general phenomenon across several species (Lattal & Metzger, 1994), classes of responses (Critchfield & Lattal, 1993), and environmental arrangements (Lattal & Gleeson, 1990; Wilkenfield, Nickel, Blakely, & Poling, 1992). The present experiments examined the role of another variable, body weight, in the acquisition and subsequent maintenance of responding with delayed reinforcement.

Body weight is among those variables that are traditionally discussed under the rubric of motivation. Michael (1982) proposed the

concept of establishing operations as an alternative description of motivational variables because it emphasizes the environmental determinants of behavior. An establishing operation both renders events effective as reinforcers and "simultaneously alters the momentary frequency of the behavior that has been followed by that reinforcement" (Michael, 1982, pp. 150-151). For example, restricting access to food establishes it as reinforcer for responses that produce it. Both Michael (1982) and Segal (1972) suggested that another effect of food restriction is to evoke either increased general activity or specific responses. Once responses are evoked, they are more likely to persist because they are followed by food.

Although reinforcer restriction increases the general or spontaneous activity of rats (Reed, 1947), evidence that restriction increases specific responses of experimentally naive rats is mixed. Schoenfeld, Antonitis, and Bersh (1949) and Bruner and Victor (1992) showed that experimentally naive water-deprived rats placed in an operant conditioning chamber emitted responses on an operandum in the absence of any reinforcing consequence. The number of nonreinforced responses diminished both within and between successive daily sessions. Neither experiment, however, involved comparisons of

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the operant levels of the water-restricted animals with the operant levels of animals that were sated. Data from other experiments in which operant levels of sated and food-restricted animals were compared have not shown a consistent relation between food restriction and nonreinforced responding. For example, Murray (1953) found that 23-hr food-deprived rats did not differ from sated rats in the number of responses emitted to a short lever (2.17 in. long, extending 0.5 in. into the chamber) when responses were not reinforced. The 23-hr food-deprived rats, however, responded significantly more on either a long lever (4 in. long, extending 0.5 in. into the chamber) or a chain-pull operandum than did sated animals. Segal (1959) found that sated rats emitted significantly more spontaneous (nonreinforced) lever presses (on a 2-in. long Gerbrands lever that extended 0.5 in. into the chamber) during the first 15 daily 25-min sessions of enclosure in an operant chamber than did rats restricted to either 91% or 83% of ad libitum body weight (hereafter, ad libitum weight). For the second 15 sessions of the experiment, there were no differences in the numbers of lever presses emitted by animals maintained at the different body weights.

Body weight, or other means of food restriction, may affect operant responding maintained by immediate reinforcement. Such effects are modulated, however, in part by the reinforcement schedule used to maintain behavior. For example, higher response rates on variable-interval (VI) schedules of reinforcement have been obtained when rats were deprived of food for 23 to 24 hr versus 0 to 10 hr (Clark, 1958). Using a VI omission schedule that resembled a differential-reinforcement-of-low-rate (DRL) schedule, Lewis and Dougherty (1992) reported higher response rates as pigeon's body weights decreased from 90 to 70% ad libitum. However, Conrad, Sidman, and Herrnstein (1958) found that the response rates of rats and a monkey exposed to DRL schedules under several different conditions involving hours of food deprivation differed only by a few responses per minute (cf. Kramer & Rilling, 1970).

Body weights in previous investigations of response acquisition with delayed reinforcement have varied. Lattal and Gleeson (1990)

maintained animals at 70% of their ad libitum weights to facilitate a high level of activity and a vigorous approach response to the food magazine (see also Critchfield & Lattal, 1993). Wilkenfield et al. (1992) established lever pressing by rats with delayed reinforcement in a single 8-hr experimental session with the animals at 80% of their ad libitum weights at the onset of the session. Dickinson, Watt, and Griffiths (1992) and van Haaren (1992) used 22.5-hr and 23-hr food restriction regimens, respectively. Extrapolating Reese and Hogenson's (1962) observations about the relation between percentage of ad libitum weight and hours of food deprivation of pigeons, these latter deprivation regimens correspond to around 85% of ad libitum weight.

The preceding review suggests that, whether food deprived or not, an experimentally naive animal is likely to emit occasional spontaneous responses. Such responses, however, may be more affected by delayed reinforcement with greater food deprivation because greater deprivation, in Michael's (1982) terms, should more strongly establish the food as a reinforcer. In that procedural and apparatus differences in previous studies preclude direct comparisons of such effects, the present experiments investigated the relation between responding and delayed reinforcement as a function of body weight.

## EXPERIMENT 1

Experiment 1 was conducted to compare systematically the effect of 70%, 80%, and 90% of ad libitum body weight on both response acquisition and response rates that were subsequently maintained by delayed reinforcement.

### *Method*

*Subjects.* Experimentally naive female Sprague-Dawley rats were used. The ages of the rats ranged between 224 and 332 days at the start of the experiment. Each rat's age during its first session of the experiment is shown in Table 1. Five rats each were maintained at 70%, 80%, or 90% of their individual free-feeding weights. Each rat's ad libitum weight, target weight, and the mean and range of the weights for all sessions of Experiment 1 are also shown in Table 1. Ad libitum

Table 1

For each rat, age (in days) during its first session of the experiment, ad libitum weight, target weight, and mean and range of daily weights during Experiment 1. All weights are in grams.

70% ad libitum body weight					
	Rat 1	Rat 4	Rat 7	Rat 10	Rat 13
Age (days)	228	231	314	278	304
Ad libitum weight	406	385	417	328	423
Target weight	284	270	291	230	296
Mean weight	286.4	271.0	290.4	230.7	297.9
Range	280–290	267–277	286–296	223–240	290–304
80% ad libitum body weight					
	Rat 2	Rat 5	Rat 8	Rat 11	Rat 14
Age (days)	224	227	270	266	304
Ad libitum weight	357	439	317	359	346
Target weight	286	351	254	287	277
Mean weight	286.7	351.1	253.7	288.5	275.7
Range	281–290	342–359	248–260	283–294	270–284
90% ad libitum body weight					
	Rat 3	Rat 6	Rat 9	Rat 12	Rat 15
Age (days)	214	224	309	261	322
Ad libitum weight	356	399	413	372	344
Target weight	320	359	372	335	310
Mean weight	316.0	357.4	367.5	334.0	308.3
Range	302–322	351–364	363–378	329–342	303–316

body weight was based on the mean weights obtained over the 5 to 7 days immediately preceding implementation of food deprivation. Prior to and during assessment of ad libitum body weights, each animal had continuous access to both food and water. When the food-restriction regimen was implemented, water continued to be freely available in each rat's home cage.

*Apparatus.* A Gerbrands Model G7010 rat chamber enclosed in a sound-attenuating ventilated enclosure was used in each experiment. The chamber was 20.5 cm wide by 19.5 cm high by 23.5 cm long. The work panel contained a rat lever (Gerbrands Model G6312) that was 5.0 cm long and extended 1.5 cm from the work panel. The center of the lever was located on the midline of the work panel, with the top of the lever 8.0 cm from the chamber floor. The lever required a force of 0.25 N to operate. The work panel also contained a recessed feeder tray and a houselight. The feeder tray was located in a recess (4.5 by 4.5 cm) 4.0 cm to the left of the midline of the work panel, with the bottom edge of the recess 0.75 cm from the chamber floor. The center of the houselight

was 10.0 cm from the floor and was centered on the feeder tray recess. This houselight was illuminated continuously during the session. Reinforcers were single 45-mg Noyes Precision food pellets delivered via a Gerbrands Model G5100 pellet dispenser that made a click sound during operation. In an adjacent room, a Tandy 1000 EX personal computer using MED Associates MedPC® software (Version 3.1) controlled the experiment.

*Procedure.* Each rat was first exposed to five sessions wherein it was placed in the chamber with the houselight illuminated. During both this phase and subsequent magazine training, one of the experimenters observed the animal continuously through a peephole in the sound-attenuating enclosure door. A 5-g cache of food pellets was available in the food tray at the beginning of the session. The rat was allowed to explore the chamber, approach the food tray, and eat the food. As the rat consumed the food, the feeder was activated on a fixed-time (FT) 15-s schedule. The FT interval was interrupted when the rat moved more than 10 cm away from the food tray for more than 5 s, and the schedule was reinstated at the point of interruption when

the rat next touched a pellet in the feeder with its paws or nose and mouth. This preliminary training introduced the rats to the location of the feeder tray and acclimated them to the sound of the feeder. This training helped to ensure that even those rats with the highest body weight (90% of free-feeding weight) would contact the food in the tray. Each of these first five sessions lasted for 30 min or until all of the pellets in the tray had been consumed, whichever occurred first.

Next, magazine training of the rats occurred. Each rat was placed in the illuminated chamber as before, but food was not available in the food tray at the beginning of the session. Soon thereafter a food pellet was delivered, and the time between the delivery of the food pellet and its consumption was measured. Food pellets continued to be delivered according to a variable-time (VT) 15-s schedule of reinforcement comprised of 20 interfood intervals arranged according to the distribution provided by Fleshler and Hoffman (1962), and the time intervals between pellet delivery and pellet consumption were recorded. Pellet delivery was defined by the operation of the feeder and consumption by the rat grasping the pellet and placing its mouth to the pellet. The VT schedule remained in effect until the rat consumed 20 consecutive food pellets each within 2 s of delivery, or until the rat ceased approaching the feeder and eating. The latter criterion was defined by a failure to consume a delivered pellet within 1 min of its delivery. If approach and eating ceased, subsequent sessions followed the same procedure until the 20-pellet consumption criterion was met. In the session immediately following the one in which the 20-pellet criterion was met, the consumption of 10 consecutive pellets within 2 s of delivery was required.

Immediately after the 10-pellet criterion was met (i.e., during that same session), a delay-of-reinforcement procedure was effected. No attempt was made to shape lever pressing through the differential reinforcement of successive approximations or otherwise explicitly train the lever-press response. Rather, the animal simply remained in the chamber, and lever presses were reinforced according to a tandem VI 15-s differential-reinforcement-of-other-behavior (DRO) 30-s schedule of reinforcement. This schedule defined an

unsigned resetting delay of reinforcement procedure. The VI schedule values were selected based on the distribution described by Fleshler and Hoffman (1962). Under this schedule, the first lever press after an average of 15 s initiated a 30-s unsigned interval (the delay) during which every lever press restarted the 30-s interval. Thus, food pellets were never delivered within 30 s of a lever press. This procedure remained in effect for 20 sessions. One hour following the end of each session, those rats that required supplemental feeding to maintain the appropriate body weight were fed an appropriate number of 5-g Purina rat pellets. Sessions occurred daily, 7 days per week, and ended after 2 hr or 60 food pellet deliveries, whichever occurred first.

### *Results and Discussion*

The numbers of sessions required for magazine training of each of the subjects are shown in Table 2. The criterion for magazine training was met during the first two sessions for each rat except Rats 14, 9, and 12. Lever pressing did not occur during either the five initial sessions or during magazine training. The response rates of each subject for each session under the delay-of-reinforcement procedure are shown in Figure 1. Response rates were calculated here and in the subsequent experiments by dividing the total numbers of responses in a session by the total amount of session time. Overall response rates were used rather than only the VI component response rates. Response rates were sufficiently low that it was not unusual for interfood intervals arranged by the VI schedule to lapse before the first response in that interval occurred. As a result, response rates in the initial VI component were often unusually low, and overall rates seemed to be a valid index of control by the tandem schedule. Each of the subjects in the 70% ad libitum weight group pressed the lever during the first session following magazine training. Each rat in the 80% ad libitum weight group had lever pressed at least once by the second session, although responding was not sustained by some of the rats until subsequent sessions. Four of the 5 subjects in the 90% ad libitum weight group had pressed the lever at least once by Session 12; however, the 5th subject (Rat 15) in this group never pressed the lever.

Table 2

Number of consecutive pellets consumed within 2 s of presentation (top number) and session length in seconds (bottom number) during successive sessions of magazine training for each rat in Experiment 1. Missing data are indicated by dashed lines.

Rat	Successive sessions		
	1	2	3
70% ad libitum body weight			
1	20	10	
	1,023	191	
4	20	10	
	543	744	
7	20	10	
	373	126	
10	20	10	
	673	90	
13	20	10	
	648	349	
80% ad libitum body weight			
2	20	10	
	1,162	334	
5	20	10	
	1,488	589	
8	20	10	
	608	140	
11	20	10	
	918	170	
14	12	20	10
	978	376	159
90% ad libitum body weight			
3	20	10	
	—	—	
6	20	10	
	1,715	368	
9	0	15	14 <sup>a</sup>
	829	893	—
12	14	20	10
	1,505	772	349
15	20	10	
	365	371	

*Note.* Sessions ended if there was a latency of greater than 1 min between pellet delivery and consumption. See text for further description.

<sup>a</sup> For Rat 9, seven sessions were required to reach the criterion for magazine training. The number of pellets consumed (and the session lengths) in Sessions 4 through 7 were 13 (—); 19 (411 s); 20 (996 s); 10 (362 s).

Once started, lever pressing continued during subsequent sessions for all of the rats maintained at 70% ad libitum weight and for 4 of the 5 rats maintained at 80% ad libitum weight. Lever pressing by rats maintained at 90% ad libitum weight was not as well sustained as that by the rats in the other two body weight conditions.

A Kruskal-Wallis analysis of variance by ranks (Hays, 1965) yielded a statistically significant difference in mean response rates over the 20 sessions among the groups,  $F(2, 14) = 9.09$ ,  $p < .01$ . Response rates were consistently higher for the rats maintained at 70% ad libitum weight, responding by subjects in the 80% ad libitum weight group was not as consistent and the rates were lower, and response rates in the 90% ad libitum weight group were much lower than in the other groups.

One potential difficulty in interpreting the results of this experiment was the fact that, despite the use of a common magazine-training criterion for rats at each of the body weights, some of the rats at 90% ad libitum weight required more time to reach the magazine training criterion than did those at 70% ad libitum weight. A second potential difficulty was that, because response acquisition was of primary interest, it was necessary to compare the body weight effects across groups of animals rather than within individual subjects. As a result, it was not possible to determine the effects of different body weights on responding of individual subjects.

## EXPERIMENT 2

Experiment 2 was conducted to examine further the possibility that the slower response acquisition exhibited by the rats deprived to 90% of their ad libitum weights in Experiment 1 was related to magazine training. In the second experiment, magazine training of each rat occurred at 70% ad libitum weight, and thereafter weights were adjusted according to the experimental design. In contrast to Experiment 1, the design also permitted within-subject comparisons of body weight effects on responding.

### Method

*Subjects.* Each of 3 female Sprague-Dawley rats was maintained at 70% or 90% of its ad libitum weight in different phases of the experiment. Both body weights were calculated as described in Experiment 1. Table 3 shows, for each rat, its age (in days) during its first session of the experiment, ad libitum body weight, target weight, and the mean and range of the body weights during each condition of Experiment 2.

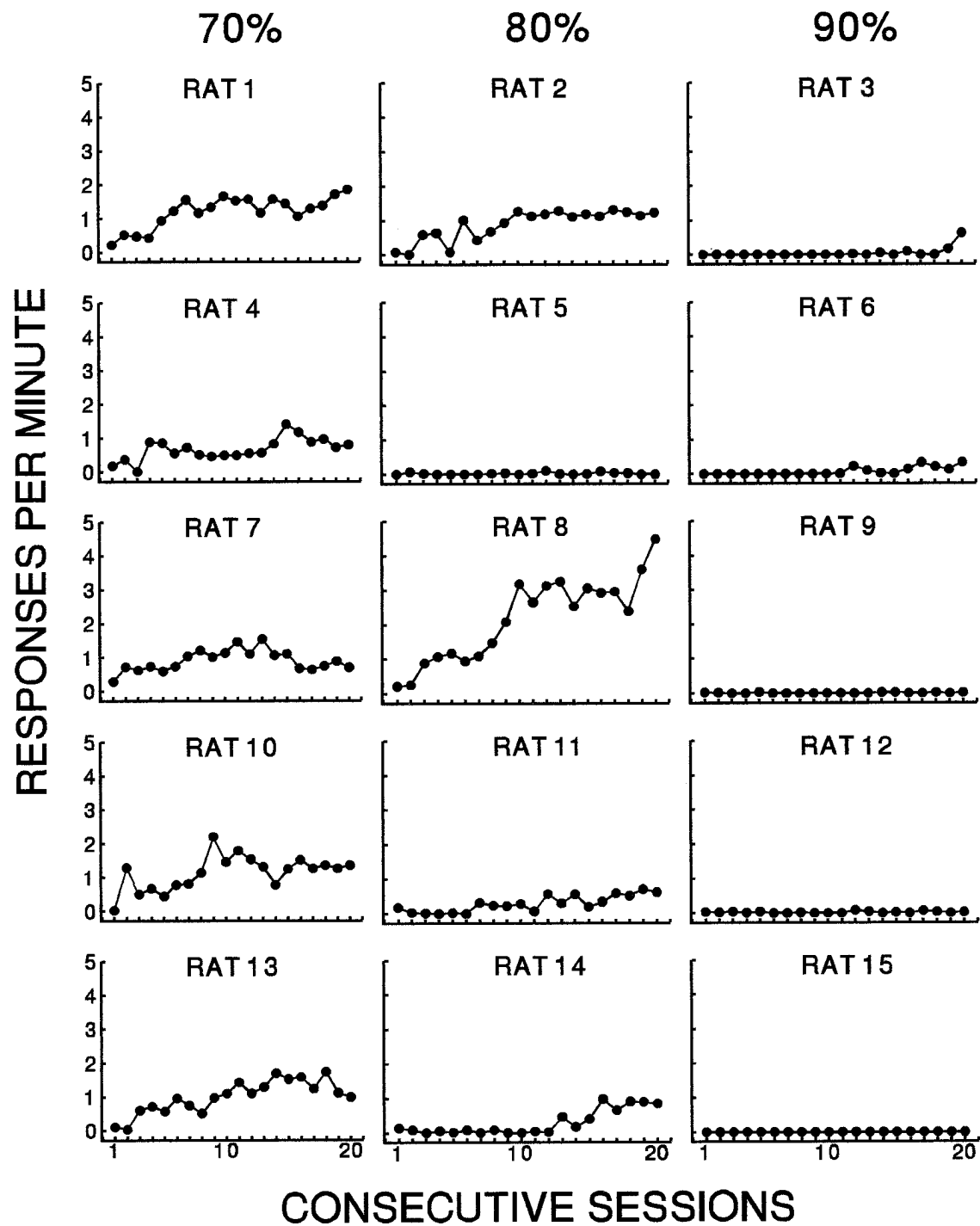


Fig. 1. Responses per minute (total responses divided by total session time) for each rat during each of the 20 sessions of Experiment 1.

Table 3

For each rat, age (in days) during its first session of the experiment, ad libitum weight, target weight, and mean and range of daily weights during each condition of Experiment 2. All weights are in grams.

	Rat 16			Rat 17			Rat 18		
	Condition 1	Condition 2	Condition 3	Condition 1	Condition 2	Condition 3	Condition 1	Condition 2	Condition 3
Age (days)	223			223			223		
Ad libitum weight	244			264			261		
Target weight	220	171	220	238	185	238	235	183	235
% ad libitum weight	90	70	90	90	70	90	90	70	90
Mean weight	222.2	173.0	219.8	240.0	184.8	238.1	235.7	183.3	235.5
Range	215–226	169–179	215–224	232–243	180–190	232–243	230–240	177–188	231–240

*Apparatus.* The apparatus was the same as that used in Experiment 1.

*Procedure.* The details of the procedure were as described in Experiment 1, with the following exceptions. During the period of access to the cache of pellets in the food hopper and during magazine training, each rat was food deprived to 70% of its ad libitum weight. Once each rat reached the final 10-pellet consumption criterion, rather than starting the first session the rat was removed from the chamber. Over the next 7 to 10 days the weight of each rat was increased gradually to 90% of its ad libitum weight by increasing the daily ration of food. Experimental sessions were not conducted during this transition period. Only when the 90% weight was attained was the experiment restarted. At this point, the animal was placed in the chamber on successive sessions in the presence of the

tandem VI 15-s DRO 30-s schedule of reinforcement described in Experiment 1.

After 20 sessions on the schedule at 90% ad libitum weight, the weight of each rat was decreased to 70% ad libitum weight over 11 to 15 days by limiting the rat's daily food ration. Experimental sessions were suspended during the transition period. When the 70% ad libitum weight was attained, 20 additional sessions under the tandem VI 15-s DRO 30-s schedule were conducted. Thereafter, the body weight of each rat again was increased to 90% over 8 to 9 days, with experimental sessions suspended during the transition period. When 90% of ad libitum weight was reached, 20 additional sessions under the same tandem schedule occurred.

### Results and Discussion

The data in Table 4 show that each rat met the magazine training criterion within two sessions. Lever pressing did not occur during the five initial sessions or during magazine training. Figure 2 shows overall response rates during each session of the experiment. The data for the original Session 16 in the first condition were lost because of a computer malfunction; thus, only 19 sessions are shown for that condition. Each of the subjects lever pressed at least once during the first session and then continued to respond, but at low rates, in the following sessions at 70% ad libitum weight. Response rates of Rats 16 and 17 increased over several sessions when the body weight was changed from 90% to 70%. Rat 18's mean response rates also were slightly higher during the last six sessions at 70% compared to the last six sessions of the first

Table 4

Number of consecutive pellets consumed within 2 s of presentation (top number) and session length in seconds (bottom number) during successive sessions of magazine training for each rat in Experiment 2. Missing data are indicated by dashed lines.

Rat	Successive sessions	
	1	2
16	20	10
	—	312
17	20	10
	690	728
18	20	10
	—	—

*Note.* Sessions ended if there was a latency of greater than 1 min between pellet delivery and consumption. See text for further description.

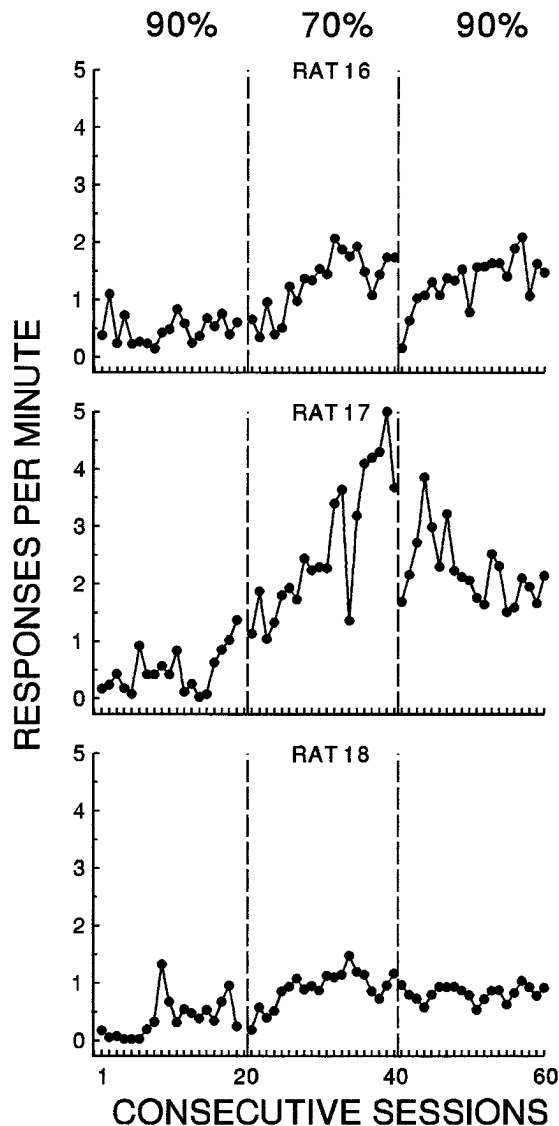


Fig. 2. Responses per minute (total responses divided by total session time) for each rat during each session of each 20-session condition of Experiment 2. The data for Session 16, in the first condition, were lost because of a computer malfunction.

90% ad libitum weight condition; however, there was substantial overlap with the rates in the first condition. When Rats 16 and 17 were returned to the 90% ad libitum weight condition, their response rates initially dropped, perhaps in part because of the absence of experimental sessions during the transition period. Thereafter, the response rates increased such that only the mean response rates of Rat

17 at the end of this condition could be considered lower than in the preceding 70% ad libitum weight condition. Even with this rat, the overlapping ranges between the last few sessions of the 70% and 90% ad libitum weight conditions call into question whether the differences between the two body weights on maintained responding were reliable.

In Experiment 1, rats acquired an operant response differentially according to the body weight at which they were maintained. The results of Experiment 2 suggest that restricting rats to 70% of their ad libitum weights during magazine training leads to more consistent responding during the acquisition of behavior with delayed reinforcement, even when the first exposure to the delay contingency is at 90% ad libitum weight. Indeed, the response rates of each of these 3 rats were higher and more consistent across sessions than were the rates of any of the rats maintained at 90% ad libitum weight in Experiment 1.

These results also suggest that body weight is not critical in maintaining responding with delayed reinforcement, once such responding is established reliably. In particular, the comparison of response rates between the 70% condition and the last 90% ad libitum weight condition showed little evidence of systematic differences in response rates.

### EXPERIMENT 3

Experiments 1 and 2 were conducted to examine the role of different percentages of ad libitum weight in establishing new behavior with delayed reinforcement immediately following magazine training. The first two experiments together suggest that body weight during magazine training is important in response acquisition with delayed reinforcement. In the final experiment, we investigated further how magazine training itself interacts with body weight in establishing behavior with delayed reinforcement. In contrast to the magazine training of the first two experiments, rats that were maintained at either 70% or 90% of their ad libitum weights were exposed to the delay-of-reinforcement procedure in the absence of any prior magazine training.

Table 5

For each rat, age (in days) during its first session of the experiment, ad libitum weights, target weights, and mean and range of daily weights during Experiment 3. All weights are in grams.

	Rat 19	Rat 20	Rat 21	Rat 22
Age (days)	334	326	387	390
Ad libitum weight	327	324	366	332
Target weight	229	292	256	299
% ad libitum weight	70	90	70	90
Mean weight	232.0	289.9	258.8	301.1
Range	223–235	285–296	252–264	293–306

### Method

**Subjects.** Four female Sprague-Dawley rats were used. Two each were maintained at 70% and 90% of their free-feeding weights as described in the first experiment. Table 5 shows, for each rat, its age (in days) during its first session of the experiment, ad libitum body weight, target weight, and the mean and range of weights during each condition of Experiment 3.

**Apparatus.** The apparatus was the same as that used in Experiment 1.

**Procedure.** The details of the procedure were as described in Experiment 1 except as noted. Neither the five-session access to the pellet cache in the food hopper nor the magazine training used in the first two experiments was employed. No attempt was made to shape lever pressing through the differential reinforcement of successive approximations or otherwise explicitly train the lever-press response. Rather, during the first session and for the 29 sessions thereafter, for a total of 30 sessions, the animal simply was placed in the chamber and lever-press responses were reinforced according to the tandem VI 15-s DRO 30-s schedule of reinforcement. The number of sessions was extended to 30 in this experiment because of the number of sessions with either no or unusually low rates of responding during the early part of the experiment.

### Results and Discussion

The overall response rates of each subject during each of the 30 sessions are shown in Figure 3. Three of the 4 subjects lever pressed consistently under the delayed reinforcement procedure within 13 sessions, in the absence of either magazine or lever-press training. During the last 15 sessions, the response rates

of the rats maintained at 70% of ad libitum weight were higher than those of the rats maintained at 90% of ad libitum weight.

After 20 sessions the response rates of Rats 19 and 21 were comparable to those of rats in Experiment 1 maintained at 70% of ad libitum weights. The response rates of Rat 20 were higher than, and those of Rat 22 were comparable to, those of the rats in Experiment 1 that were maintained at 90% of ad libitum weights.

The results of Experiment 3 suggest that responding can be established and maintained with delayed reinforcement at either high or low body weights without any magazine training or prior exposure to the source of the reinforcer. Consistent with the findings of Experiment 1, responding seemed to develop less reliably when body weight was higher.

## GENERAL DISCUSSION

The results of these three experiments extend previous research that has demonstrated response acquisition with delayed reinforcement (e.g., Dickinson et al., 1992; Lattal & Gleeson, 1990; Skinner, 1938; van Haaren, 1992; Wilkenfield et al., 1992) by showing that (a) such response acquisition is more likely at body weights that are lower percentages of ad libitum weights, (b) subsequent response maintenance with delayed reinforcement is less reliably related to body weight, (c) reducing body weight during magazine training leads to faster acquisition even if body weight is increased before exposure to the delayed reinforcement procedure, (d) magazine training is unnecessary in establishing new behavior with delayed reinforcement, but (e) acquisition proceeds more rap-

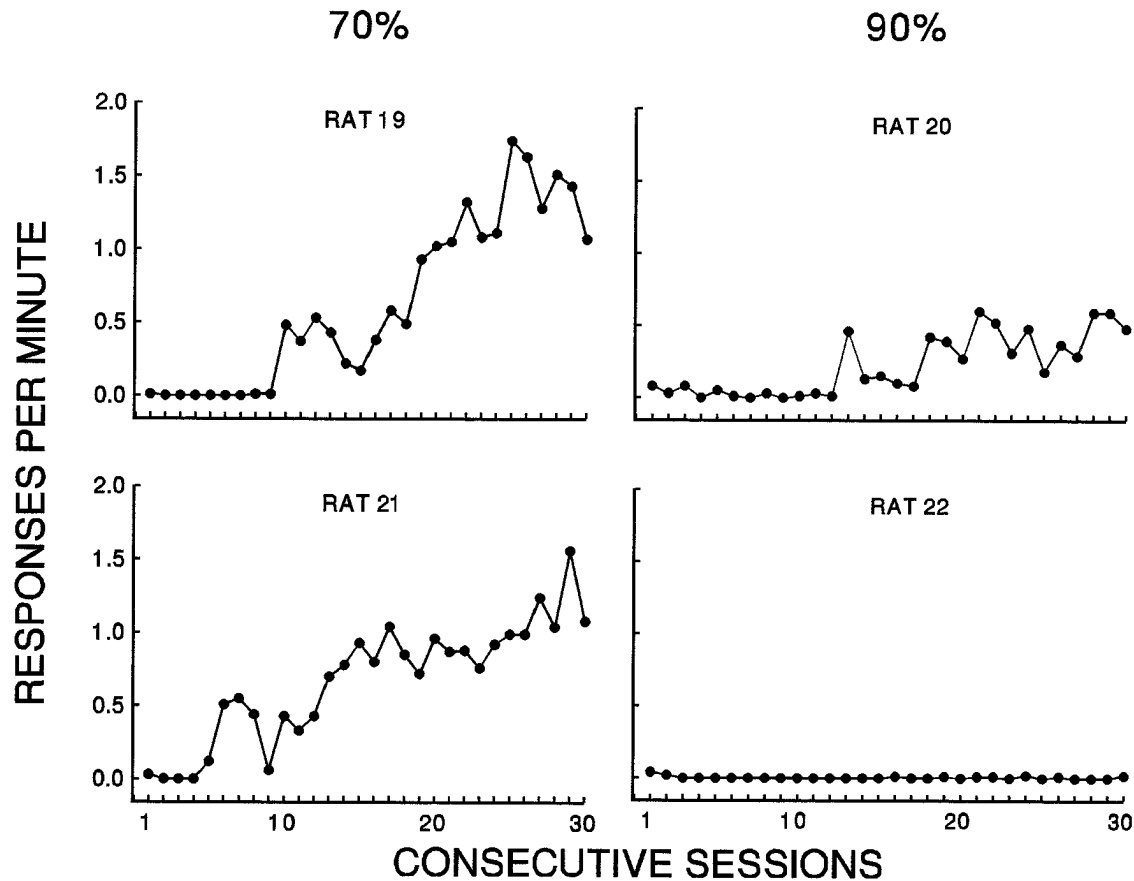


Fig. 3. Responses per minute (total responses divided by total session time) for each rat during each of the 30 sessions of Experiment 3.

idly with magazine training and when such training occurs at lower, rather than higher, body weights. These findings are relevant to a discussion of four stages in the establishment of behavior with delayed reinforcement in the absence of response training: (a) establishing a reinforcer and ensuring contact of the organism with that reinforcer, (b) the occurrence of the first instances of the response, (c) the transition from operant level to steady state, and (d) the final steady state of responding.

#### *Establishing a Reinforcer and Contact With It*

As a general rule, restricting food access is a necessary but not sufficient condition to establish food as a reinforcer. The food will function as a reinforcer only if it is contacted and then consumed reliably upon presenta-

tion. One way of ensuring the contact of the organism with the food is through magazine training. "The animal must learn that the pellet [of food] is edible, that it is to be found in a particular place, that it only appears there following the sound of the food magazine, that the sound comes after the lever has been depressed" (Sidman, 1960, p. 296).

Differences in the effects of body weight on response acquisition might be expected if different body weights yield differences in the adequacy of magazine training. Because an animal at a higher body weight is less likely to approach a food pellet, the animal may be less controlled by the subsequent response-food delivery relation than a more deprived one, in part as a function of differences in magazine training. In the first experiment, all animals were trained to a common criterion of approaching the food magazine, ruling out

differences in degree of magazine training as the determinant of the behavioral differences observed between the rats in the different groups. The speed with which magazine training was accomplished for rats in the different groups, however, differed, with animals at 70% ad libitum weight training the most rapidly. In Experiment 2, rapid magazine training also occurred (at 70% ad libitum weight), which, in contrast to Experiment 1, subsequently led to acquisition by all 3 animals at 90% ad libitum weight. In Experiment 3, responding was established without magazine training; however, even with the animals maintained at 70% ad libitum weight, consistent responding developed more slowly than it did for animals in the first experiment that were similarly deprived but magazine trained.

#### *First Instances of the Response*

Skinner observed that the "the rat must press the lever at least once 'for other reasons' before it presses it 'for food'" (1969, p. 175). The operant level of a particular response in a new situation may result from the species' phylogenetic history of interactions with particular environments or from a previous history of reinforcement of the response. Particularly the latter circumstance suggests that environmental factors might be manipulated to influence the first instances of a response (i.e., its operant level) and thereby the likelihood that the response will contact the reinforcer.

In the introduction we noted Segal's (1972) and Michael's (1982) suggestions that restricting access to food both establishes food as a reinforcer for responding and may evoke responses that later may be reinforced. Segal observed that "deprivation need neither raise the probability of all topographies nor increase the responsiveness to all stimuli. It is enough if it does so selectively, just so some minimal unit is made available for operant shaping to work upon" (1972, pp. 7-8). Without shaping or other response training, however, the final unit rather than the minimal unit must occur.

Restricting food access is necessary for the food to function as a reinforcer, but the effects of such restriction on evoking responding of experimentally naive animals is less clear. Although both deprived and nonde-

prived rats emit occasional responses in the absence of reinforcement, restricting food access does not necessarily make a *specific* response more likely. In the introduction we noted that, using levers nearly identical in dimensions to the one used here, Murray (1953) showed that deprived rats were less likely to press than sated ones and Segal (1959) showed that rats with restricted access to food pressed a lever less frequently in early sessions of the experiment than did sated rats. The results of Murray and Segal seem to preclude a simple account of the results of the present experiments in terms of different body weights differentially activating the animal and thereby making the evocation of lever-press responses more likely. An alternative account appears in the next section.

#### *The Transition from Operant Level to Steady State: The Role of the Delay Contingency in Developing Responding*

Response acquisition is a transition state wherein the rate of responding is near zero early in the state and increases over time as a function of the response-reinforcer relation (cf. Sidman, 1960). These transitions occur both within and across sessions. In the absence of a dependency between responding and reinforcement after a delay, responding neither develops nor is maintained (Latval & Gleeson, 1990, Experiments 1 and 3). The present experiments extend the analysis of response acquisition with delayed reinforcement by showing that the transition is more rapid with lower body weights and when magazine training occurs. Body weight therefore seems to affect response acquisition because of the response-reinforcer relation. An animal placed in an operant chamber is likely to emit at least an occasional response, more or less independently of its body weight. If such a response is followed by a reinforcer, as in the present experiments after an unsignaled delay interval, further responding is determined by the animal's body weight. That is, once a response occurs and some time is later reinforced, the body weight of the animal interacts with the reinforcer as a function of the response-reinforcer dependency thereby established to determine the likelihood of the next response.

*Asymptotic (Steady-State) Responding*

Once responding was established in these experiments, the response rates of animals maintained at different percentages of ad libitum body weight were more similar than during acquisition. For example, in absolute terms, the response-rate differences were small at the end of the 70% and 90% ad libitum weight conditions in Experiment 2 (only between one or two responses per minute). Similarly, these response-rate differences were also small in Experiment 3 between Rat 20 at 90% and Rats 19 and 21 at 70% ad libitum weight.

These small differences in terminal performance under the different body weights may reflect steady-state control of the responding by the DRO 30-s schedule. This schedule in turn may minimize differences in response rates under conditions of delayed reinforcement as a function of body weight. Body weight differences therefore may determine responding within a narrow window between the first response and what might be called full contact with the contingency during the steady state, where the DRO 30-s schedule sets a stringent upper limit on response rate.

Many schedules of immediate reinforcement of responding involve positive feedback relations (Nevin & Baum, 1980) in which higher response rates yield more reinforcers in time than do lower rates. This is strongly the case with fixed-ratio schedules but more weakly so with VI schedules. It therefore is not surprising that steady-state operant response rates increase with decreasing body weight under such schedules, as described in the introduction. A DRL schedule is more complicated in that it involves both negative and positive feedback relations. Responding during the interreinforcer interval resets the interval, but a response after the interval lapses is reinforced immediately. This complicated relation may account for the small differences in response rate as a function of hours of food deprivation found by Conrad et al. (1958). The present tandem schedules similarly involved both positive and negative feedback relations in that a response was required to initiate the delay but, once initiated, further responding during the delay interval further delayed reinforcement. The results here were similar to those of Conrad et al. in that

body weight had relatively small effects on maintained responding, presumably because of the ceiling that the tandem schedule placed on response rates.

*Other Implications*

The present experiments relate generally to an understanding of the minimal conditions necessary for the reinforcement of operant behavior, the analysis of transition states, and the nature and description of delay of reinforcement effects.

Skinner (1948) suggested that even in the absence of any programmed response-reinforcer relation, behavior and events that follow sometimes combine in systematic ways to develop and maintain consistent patterns of responding, a phenomenon he labeled *superstition*. Although the evidence for superstitious behavior has been questioned (e.g., Staddon & Simmelhag, 1971), the concept of behavior developing and thereafter being maintained under minimally specified contingencies seems to be an important one. This concept is supported by studies of response acquisition with delayed reinforcement. Consider, for example, the behavior of Rat 6 in Experiment 1. Responding developed slowly but eventually emerged and was maintained despite the absence of any response training, a long delay between the response and reinforcer, and the fact that the animal was maintained at 90% of its ad libitum body weight. Rat 20, in Experiment 3, offers an even more dramatic example, in that not only did the preceding conditions prevail but this rat also received no magazine training.

As noted above, response acquisition with delayed reinforcement is a transition state between the operant level and steady-state maintenance of responding by the schedule conditions, including the delay to reinforcement. To the extent that the parameters of variables contributing to the duration of any transition are understood, those variables can be arranged such that transition states are of minimal duration (Sidman, 1960). Despite the consistency of the finding of response acquisition with delayed reinforcement, there have been only a few investigations of differential acquisition as a function of other variables. Wilkenfield et al. (1992) found an inverse relation between response acquisition and delay duration for different groups of rats when

the delay was defined by a DRO schedule of 0 to 32 s in duration. The present experiments demonstrated differential acquisition as a function of both body weight and the presence or absence of magazine training. The analysis of each of these variables suggests ways of minimizing the transition from operant level to sustained responding under a schedule of reinforcement. Responding during a transition and subsequent steady-state condition is a function of both antecedent variables like body weight and the organism's behavior during the preceding steady state, whether such behavior is at the operant level or under the control of some experimenter-specified reinforcement schedule (e.g., Freeman & Lattal, 1992). Delay-of-reinforcement effects most often have been measured in the experimental analysis of behavior against a preceding steady-state baseline of responding maintained by immediate reinforcement. The discussion of the response-rate decreases that result is typically in terms of the detrimental effects of delay of reinforcement on operant behavior. When, however, delay-of-reinforcement effects are measured against the operant level of the response, responding is described as developing and being maintained. Experiments like the present ones suggest that whether delays to reinforcement are considered to have detrimental or incremental effects on responding depends critically on the steady-state baseline against which the effects are measured.

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